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AGRICULTURE THE THIRD CENTURY

INTRODUCTION TO THE ECONOMIC PROJECTIONS PROGRAM

FROM THE ADMINISTRATOR

Looking back over the 200 years of America's independence, agriculture stands out as a dynamic force in our Nation's growth. The winds of change blew especially strong across the face of agriculture as it moved from subsistence farming in 1776 to the highly mechanized and scientific industry of today. The results of this transformation have been steady uptrends in production and productivity, accompanied by downtrends in farm numbers and labor used in farming. Fewer and fewer farmers are producing more and more.

Transition in U.S. agriculture entails more than just farming, however. Although the farm production sector remains the fountainhead of raw products, the stream of agricultural abundance is increasingly fed by a farm inputs supply sector and by vast transportation, processing, and distribution sectors promoting efficiency, serving both farmers and consumers in our complex food and fiber system.

What about the next 100 years? Can this system in the third century of U.S. independence continue to deliver a cornucopia of reasonably priced food and fiber while contributing to economic growth of the Nation? Will supplies be sufficient to fill the demands of an ever-expanding world population with ever-rising purchasing power? What is the capacity for increasing food and fiber production, and what price incentives must be given to producers?

The list of related questions is too long to be recorded here. They bear on such crucial issues as the adequacy of farm income in the future and the well-being of rural people in general. . .the expected rates of technological change in the food and fiber system and how to accelerate the pace if need be. . .the likely impacts of engineered and synthetic products. . .the anticipated energy needs of the system and the costs of providing them. . .and the implications of tighter environmental controls on food and fiber output.

Ultimately, we are concerned with providing intelligence to help formulate policies and programs best suited to multiple objectives: maintaining adequate food supplies at prices consumers can afford, achieving equitable incomes for farmers, and exploiting our comparative advantage in food production in an international setting of increasing "one worldness."

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We don't claim to have precise answers to all the issues. But we do have evidence that American agriculture has a great untapped potential. To realize this potential we must first improve our information systems and intensify research that leads to better planning and wise decisions in the arena of public involvement in the food and fiber system.

The Economic Projections Program of the Economic Research Service (ERS), the results of which will be summarized in this new publication, is a renewed effort to aid policymakers and participants in the food and fiber system in an increasingly changing environment.

The closing years of American agriculture's second century are indeed marked by change—change in the supply and demand structure and change in the national and worldwide setting of agriculture's institutions. Thus, I hope that this inaugural edition of **Agriculture the Third Century** *conveys a desire, philosophy, and organization for an economic projections program that is itself as adaptive and conducive to change as the food and fiber system we study.*

Quentin M. West, Administrator

FOREWORD

Agriculture the Third Century is designed to disseminate, in as nontechnical terms as possible, the projections and analyses generated in ERS's Economic Projections Program. The emphasis in this first publication is on organization and program structure, and is thus more technical than future editions reporting analyses of emerging issues and concerns in American agriculture. Still other issues will include technical briefs on analytical models and procedures used in generating the projections used in our analyses. The nontechnical user can skip these technical briefs. But even nonspecialists will want to become familiar with such terms as scenario, alternative future, indicator, and forecasted event as these are used in organizing, conducting, and reporting our efforts to look into **Agriculture The Third Century**. These terms are defined in the glossary section of this report.

Other issues planned for this series will cover these topics:

- Historical Perspective on Agricultural Projections
- Projection Coordinating Directory
- Scenarios for Change
- Productivity Growth and Emerging Technologies
- National Food and Fiber Projections to 1985
- Regional Food and Fiber Projections to 1985—The Northeast, South, Northcentral, and West
- Farm Sector Production Capacity to 1985

Subsequent editions will be published as ERS expands its core projections capability into other sectors of the food and fiber system. Our intent is to revise each issue annually where appropriate. Also, although **Agriculture The Third Century** is the focal point for disseminating futuristic information about the food and fiber system, other analyses involving food and fiber projections are conducted in ERS and reported in technical reports and other popular publications. These analyses, while often major in scope, usually extend or add to the core projections program reported here and are often directed at a specific clientele.

TECHNICAL BRIEF ON THE ECONOMIC PROJECTIONS PROGRAM

When ERS was reorganized in 1973, the National Economic Analysis Division (NEAD) was given the responsibility for developing an additive, ERS-wide Economic Projections Program with a quick response capability.

In commenting on the ERS reorganization, Administrator West indicated renewed attention to projections, using a team approach to consolidate efforts and to insure that we work from common assumptions. Dr. West said that "as we explore alternative futures, projection teams will help assure additivity and consistency. But obviously, consistency is useless if we agree to wrong assumptions; therefore, team members will be drawn from throughout ERS representing the balanced thinking of expertise. We will still have the same high level talent. . .but coordinated."

During the past 2 years, personnel in the Economic Projections and Analytical Systems Program (EPAS), NEAD, have worked to establish an Economic Projections Program that will permit accomplishing the Administrator's goal. We have received much assistance from

the Administrator's Office, our Division Director, William T. Manley, his planning team, and many program leaders and research economists throughout ERS. This brief summarizes our accomplishments to date and our plans for the future.

Program Dimensions

Public and private policy decisions, program planning and management, and expenditures of limited Federal and State funds affect production capacity, commodity supply-demand, resource development and use, the environment, economic development, and the world food situation. The implied national goal is to provide a reasonable balance between production capacity and the need for food and fiber. More and better technical and economic information is needed to aid these processes.

We find ourselves confronted with a multitude of unprecedented and interrelated world problems in population, the environment, food, and energy requiring a systems approach for analysis. Also, public decisionmakers are increasingly turning to projections to deal with these long-run problems. Whereas, we have traditionally studied the past to understand the present, we now want to study the future to better manage the present and to better plan for the future.

The ERS approach to providing futuristic information and analysis about the U.S. food and fiber system and its major linkages with the U.S. general and world economies is a "dual thrust man-machine simulation system" illustrated in figure 1.

The left side of figure 1 represents the food and fiber system we study. We need to define the major sectors of the food and fiber system, as well as the indicators of structure and performance in each sector or connecting market. We also need to define the determinants or causal relationships associated with each indicator, including major linkages with human and natural resource development and conservation, environmental concerns, and international trade and development. When quantified, these relationships become component models of the National-Interregional Agricultural Projections (NIRAP) System illustrated in the middle of figure 1.

The NIRAP system is a computerized simulation of the food and fiber system. It can simulate alternative futures based on scenarios differing with respect to major uncertainties impacting on food and fiber, and with respect to policy decisions and programs designed to alleviate anticipated problems. By systematic scenario development and comparative analysis of alternative futures, the range of possible adjustment paths for food and fiber can be bracketed, an early warning of potential difficulties provided, and possible solutions to potential problems and tradeoffs between policy goals evaluated.

Each year, the NIRAP system is expanded to encompass a broader spectrum of the food and fiber system. A core set of scenarios is revised and resulting projections of alternative futures analyzed to provide a continual check on major issues and to provide current projections for analytical extensions of the core program; for example, ERS support of periodic national assessments of water and related land resource needs, or individual commodity or input subsector studies. Also, studies are usually being conducted for special purposes such as appraising the U.S. production capacity for food and fiber, and providing the food and fiber projections for broader general economy studies conducted by other agencies or research groups.

In addition to scenario development and the deterministic causal relationships generating normalized projections, other dimensions of the NIRAP system (when more fully developed) will include:

Shocks or unprecedented events. Independent forecasts about the food and fiber system will be collected and sorted as to their potential impact. Those events judged so unprecedented as not to be accounted for by the normalized projections based mainly on coefficients determined by regression analysis of time series data, will result in the adjustment of appropriate model coefficients so that the impact of the event, should it occur, can be estimated.

Probabilistic dimension. The probability of scenario attributes falling in specified ranges and of the unprecedented events actually happening in specified time intervals will be estimated using modified Delphi panels. Then, compounded probabilities will provide estimates of the likelihood that major indicators or variables related to specific sectors, markets, or policy goals will actually attain levels between those projected in paired alternative futures.

Interactive mode. It is not adequate to specify scenario attributes at the present and assume that no new policy decisions or unexpected

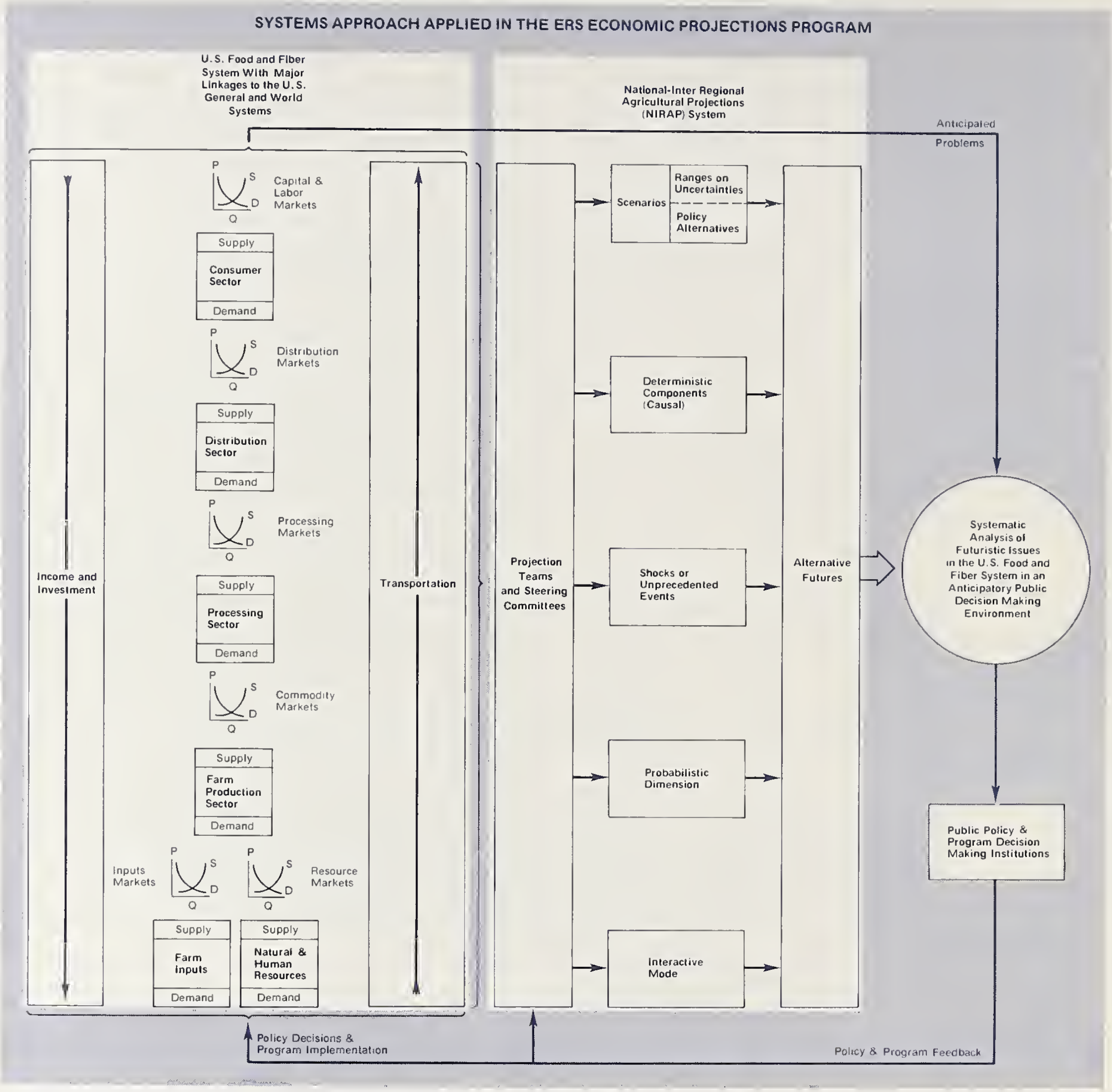

FIGURE 1

events will occur during the next 10 to 25, or even 50 years. Thus, we will experiment with different ways to stop the simulation at any point as events unfold. We will rewrite the "last act" of the scenario, including new policy decisions in reaction to undesirable levels of projected indicators and anticipated actions and counteractions by major participants in the food and fiber system. One such kind of interactive mode could be a computerized food and fiber "futurist game." Ideally, this device could provide the USDA with a "food room" much the same as a military "war room."

Paralleling the development and use of the NIRAP system is a structure of coordinated projection teams representing program areas across ERS and other Government agencies and universities. Whereas the NIRAP system provides a consistent, additive, quick response and low cost analytical capability, the coordinated projection teams capitalize on ERS's comparative advantage in economic research. ERS has a large staff of economists specializing in every major facet of American agriculture with professional contacts in other Government agencies, universities, foundations, and industry.

Technical and social scientists serving on coordinated projection teams have the first and last word as to what goes in and what comes out

of the NIRAP system. And being knowledgeable about the NIRAP system, projection team members are in a good position to link more in-depth futuristic studies with basic projections from the core program. This provides a kind of informal research matrix as illustrated in figure 2. The matrix is coordinated by the Economic Projections and Analytical Systems Program of NEAD, and it facilitates the development of a comprehensive information system covering every major issue and sector of our complex food and fiber system as we look into **Agriculture the Third Century**.

INFORMAL RESEARCH MATRIX ORGANIZATIONAL STRUCTURE OF THE ERS ECONOMIC PROJECTIONS PROGRAM

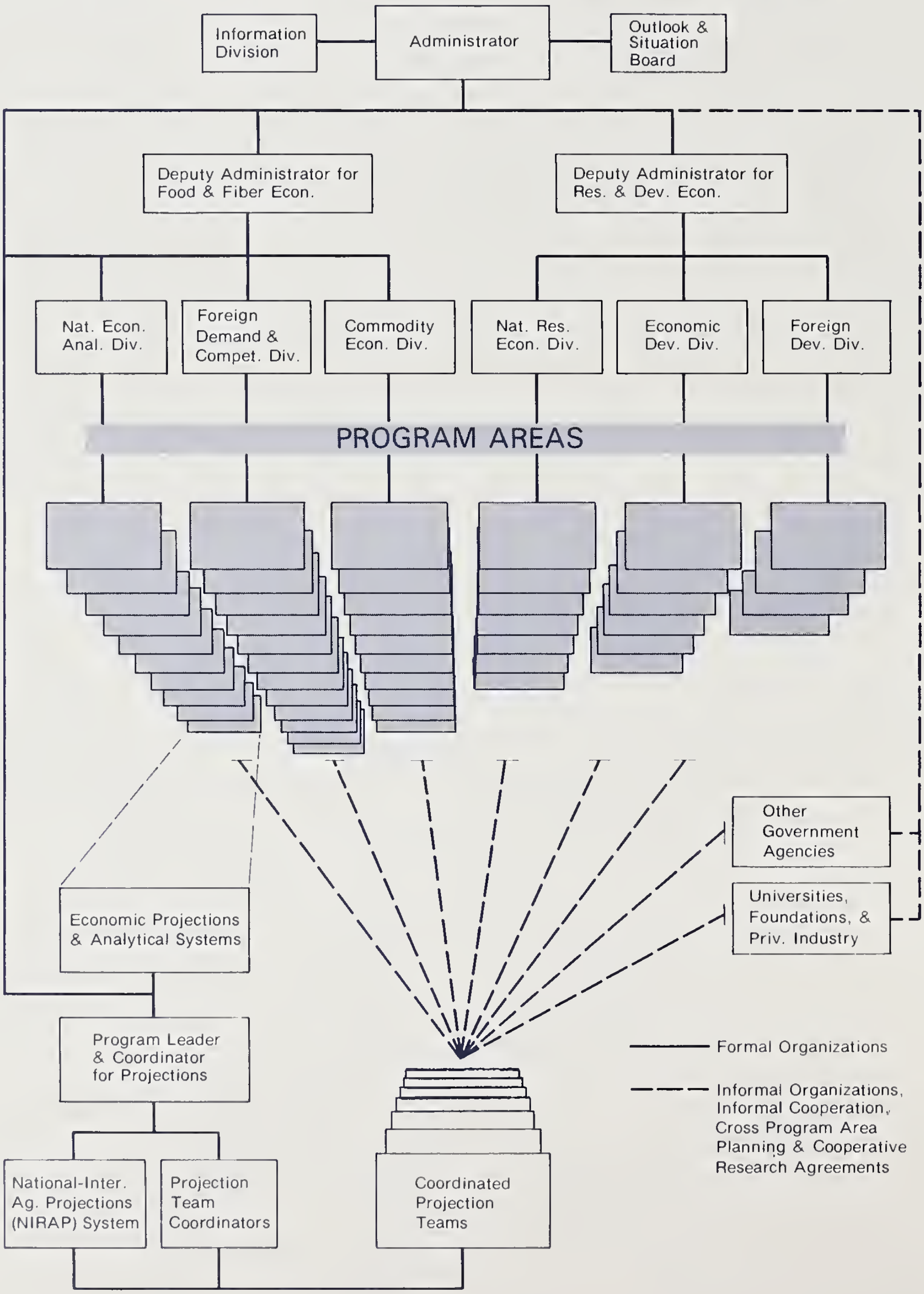

FIGURE 2

GLOSSARY

Futures research involving economic projections is just emerging as a serious line of inquiry. New terminology is creeping into economic analysis in the futuristic dimension from many different sources and sometimes with different meanings. Thus, we do not claim that the following definitions are universal, but they should be useful to users of information generated in the Economic Projections Program.

A *variable* is the name of an indicator of change, growth, structure or performance within a sector or connecting market of the food and fiber system or its major linkages with the general and world economies.

A *parameter* is a numerical coefficient specifying the causal relationship between two variables.

A *forecasted event* is an expected future development which, if it occurs, will cause some change in the assumed or projected value of a parameter or variable.

Projections are estimated future values of variables or parameters. Projections either provide the basis for assumptions or are generated consistent with specified assumptions.

A *scenario* is a precise statement of assumptions and/or projections about the future required to define the environment in which the food and fiber system will function. A scenario provides necessary information to prime the National-Interregional Agricultural Projections (NIRAP) system. Scenario statements, assumptions and/or projections are essential parts of the Economic Projections Program's total information system. However, they are inputs into the NIRAP system rather than output from it.

An *alternative future* is the resulting projections and analysis generated by a run of the NIRAP system under a specified scenario.

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AGRICULTURE THE THIRD CENTURY

THE METRIC SYSTEM

Although many uncertainties face U.S. agriculture in its third century, one thing is for sure—we will be using the metric system, without saying when. In late 1975, a law was passed setting up a Federal board to coordinate voluntary conversion of weights and measures to metric measurement. The law does not specify any deadline or proclaim a goal for an eventual national conversion, but it appears that metrication is inevitable; the United States is the only major industrial country that has not gone metric. Britain, Canada, and Australia are among the last nations converting to the metric system.

With metrication, farmers will trade in meters, kilograms, and liters rather than feet, pounds, and gallons. Agricultural statistics, USDA bulletins, and Extension leaflets will use metric units. This issue of *Agriculture The Third Century* is designed to help farmers, agribusinessmen, and others concerned with our food and fiber system prepare for the transition.

WHY GO METRIC?

It was estimated in 1960 that there would be a saving of 20 percent in the teaching of arithmetic in British schools or 5 percent in the total school time for children between 7 and 11 years. Since metric calculations are much easier, the savings in engineering time in U.S. aerospace alone could amount to $65 million a year (De Simone, 1971).

The metric system could also bring savings to our food and agricultural complex, particularly through improved marketing efficiency. Farm products are now sold by pounds, gallons, bushels, or containers of various shapes and sizes where some units have different meanings within a commodity as well as among commodities. For example, a bushel is defined as 2150.42 cubic inches in volume but its weight ranges from 60 pounds for wheat to 56 pounds for corn, 32 pounds for oats, and anywhere from 32 to 60 pounds for barley, depending on State laws (USDA, 1972). Metrication provides opportunities to simplify and standardize these units and hence to increase marketing efficiency.

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For most agricultural measurements, we need to learn only four metric units: kilograms for weights of products such as meat, vegetables, fruits, and grain; liters for liquid and dry products like milk, gasoline, oil, and flour; meters for lengths such as ropes and fences; and Celsium for temperature to replace Fahrenheit. A yield of 90 bushels of corn per acre will become 6,048 kilograms or 6.048 metric tons per hectare, a quarter section of farmland consisting of 160 acres will be 65 heactares, and a distance of 15 miles per gallon of gasoline will become 6.4 kilometers per liter. There may be some confusion at first, but the new jargon will soon become familiar as we work with it. It's just a question of adjustment.

In the long run, our agricultural trade will benefit. Engineering standards are important in international trade for measurement-sensitive products such as tractors, automobiles, machinery, and scientific instruments. Adopting standards based on the international system will foster trade. Although agricultural commodities are not particularly measurement-sensitive, international trade patterns developed by measurement-sensitive commodities will eventually affect agriculture.

Although the metric system has definite advantages over the current system, there will be considerable costs involved in the changeover, hence the delay in adopting the metric system. It will take money to make physical changes, such as modifying or buying new scales, rulers, measuring tapes, and marketing containers. Farmers and agribusinessmen will have to keep two sets of tools during the transition period. It will also cost money and time for people to learn and use the new system.

However, the cost to agriculture for physical changeover to metric will be relatively low compared to other industries. Measurements for some agricultural assets such as farm buildings, equipment, tools and machinery will change slowly; some may never change. In most cases, they will be replaced with new metric models only when they are worn out or become obsolete. Since real estate is rarely traded internationally, there would be no need to rewrite farm real estate deeds in metric units until they have changed hands and been resurveyed (USDA, 1973).

GOVERNMENT SUPPORT

In 1968, Congress commissioned a 3-year study of the metric system by the National Bureau of Standards. The study, published in 1971, concluded that adoption of the system by the United States was inevitable...and the sooner it was done the better. Since then, several Government agencies have acted to pave the way for the metric system.

- The U.S. Department of Agriculture now reports some crop yields in metric units.
- The Maritime Administration has required that all ships be built to metric specifications by 1980.
- By 1979, wine will have to be bottled in containers based on the liter.
- Schools in all 50 states are already using the metric system and many have plans to teach it exclusively in the future.
- Some private companies, especially automobile, computer, and agricultural machinery firms, are also planning metric conversions to boost export sales. Indeed, the main thrust for metric use in the United States is coming from multinational manufacturers and shippers involved in international trade—companies that must do an increasing amount of their business in international units.

Under the Metric Conversion Act of December 23, 1975, Congress put the United States firmly on the road to the metric system by establishing the National Metric Board to serve as an advisory group on metrication, to educate the public, and to submit proposals to Congress. Under guidance from the board, representatives from different sectors of the economy are expected to cooperate to bring about the greater use of international units. If the board is successful, the United States will witness a voluntary, but thorough, changeover to the metric system in the next few years.

EARLY HISTORY

The history of weights and measures is one of complexity, gradually reduced to simplicity. Ancient measurements were based on familiar objects observed in everyday life. Parts of the human body—such as the foot, thumb, and forearm—became standards for measuring length. Grains, kernels, and other seeds were used as a basis for weights, as were goat skins and baskets for volumes.

Since none of these measurements was

precise, variations from town to town and from country to country were more the rule than exceptions. Roman rule brought partial standardization to the ancient world and established measurements which bear some similarity to those now used, including the foot with 12 inches.

Roman weights and measures were exported to England and combined with native English measurements to produce the British system on which American standards are based. When the first colonists landed at Jamestown, several measurements had been standardized in England, namely, the Winchester bushel and the hundredweight. Because official copies of these standards were not generally available in America, local variations resulted. To promote uniformity, larger towns passed laws regulating weights and measures used in marketing agricultural products.

After independence, the new American Nation attempted to make weights and measures uniform over the whole country. In 1790, Secretary of State Thomas Jefferson proposed that the system be either standardized or completely revised and converted to a decimal basis like American coinage. Congress passed its first tentative law on the subject in 1799, choosing to refine the traditional Anglo-American standards used in custom houses rather than to adopt new ones.

By the early 19th century, standards were still inconsistent from State to State. Americans used more or less the same measures but slight differences persisted between areas. In most places, for example, the Winchester bushel was used to measure grain, but shippers could not agree whether to use a level bushel or heaped bushel.

Europeans had long lived with such variations in standards. Almost every country had its own system. After the French Revolution, the French government decided to drastically simplify weights and measures. Drawing on the work of Gabriel Mouton, the French in 1791 created the metric system, a unified way of measuring length, weight, and volume based on a unique measurement of the earth instead of on a variety of some arbitrarily chosen definitions.

Due to its simplicity and precision, the metric system quickly became known throughout Europe and popular among scientists. The major international breakthrough for the metric system came as a result of a conference in Paris in 1875. In the Treaty of the Meter, 17 nations agreed to set up an International Bureau of Weights and Measures that would meet periodically and provide better standards for the metric system.

Meanwhile, the United States took steps to recognize the metric system as an alternative to traditional weights and measures. In 1866, the Congress made metrics legal. Nine years later the United States was one of the countries signing the Treaty of the Meter.

Although the United States remained a long way from adopting the metric system in everyday use, the official recognition given to it by the Act of 1866 and the Treaty of 1875 created a storm of controversy. Supporters of metric measurements, speaking largely through the American Metric Bureau, argued that their system was inherently superior because of its scientific origin and simple decimal basis. Opponents contended that the costs of changing from the American system to the metric far outweighed any possible benefits and that there was no particular need for it, since most foreign trade was conducted in English measurements.

SINCE 1900...

While the metric system progressed slowly, the Government continued efforts to make the U.S. Customary System as precise as possible. Congress created the National Bureau of Standards in 1901 to oversee weights and measures and to insure their correctness. Soon thereafter, the Bureau began sponsoring annual conferences involving state and local officials to exchange information on the subject, a cooperative effort that resulted in uniform marketing of farm products and regular inspection of standards.

Although the outbreak of World War I had encouraged prometric forces to organize for another drive, they failed except for promoting the use of metrics in wartime material. For over three decades thereafter, Americans were preoccupied with other problems and Anglo-American standards remained important in world trade.

The launching of Sputnik in 1957 and increasing use of metrics by European Common Market countries rekindled the metric movement. In 1957, the U.S. Army converted to the system for weapons... Two years later the Secretary of Commerce recommended its general adoption and for the next decade the

proposal appeared before every Congress... In 1960, the General Conference of the International Bureau of Weights and Measures broadened the metric system by adding certain scientific standards and renaming it the International System of Units or SI units for short... In 1964, the National Bureau of Standards agreed to use the International System in its reports where practical.

But the single most important spur to adopt the metric system in the United States came in 1965 when Britain decided to convert to the metric system over a 10-year period. When British Commonwealth countries followed suit, the United States was left with the prospect of being the lone user of a nonmetric system of measurements.

METRIC SYSTEM: THE USER'S GUIDE

The metric system consists of 7 basic units, 2 supplementary units, 16 derived units having special names, and 13 other derived units without special names. Only the most common units associated with food, agriculture, and daily life are discussed here.

The 7 basic metric units are the meter for measuring length; the kilogram for mass or weight; the second for time; the ampere for electric current; the Kelvin (translates into degree Celsius, formerly called Centigrade) for temperature; the candela for light intensity; and the mole for molecular substance. Since second and ampere are the same units presently used and since candela and mole seldom apply to agriculture, most of us need to learn only about meters, kilograms, and degrees Celsius.

The 16 derived metric units having special names are mainly used by scientists to measure such things as force, electric resistence, and frequency. They are rarely used in agriculture.

Of the 13 other derived metric units without special names, the most commonly used are square meter for measuring area and cubic meter for volume.

The keystone for all metric units is the meter, the basic measurement unit of length. All other units are based on the meter. A meter was orginally defined as one ten-millionth of the length of the line of longitude from the equator to the North Pole, running along a line that passed near Dunkirk, France, and Barcelona, Spain. Later the standard meter was redefined as a fraction of a wave length which can be reproduced in a laboratory by any country to check the standard. A meter is slightly longer than 1 yard (1.09361 yards).

A liter, which is only slightly larger than a quart (1.057 quarts), is the common measure of volume. It is defined as one-thousandth of a cubic meter.

The standard metric unit of mass (weight) is the kilogram, defined as the mass of a liter of pure water at standard temperature and pressure. One kilogram is equal to 2.2 pounds.

Area is measured by the square meter. A commonly used unit for measuring the area of farmland is the hectare or square hectometer (10,000 square meters), which is about as large as 2½ acres (2.471 acres).

The standard unit of temperature, Kelvin, is commonly transferred to degree Celsius (°C) with 0°C being the freezing point of water and 100°C the boiling point. The normal body temperature is 37°C. The conversions of common units from customary to metric are shown in table 1 and from metric to customary in table 2.

Except for the standard unit of time, larger or smaller measures of any given metric unit can be obtained by multiplying the unit by multiples or submultiples of the powers of 10. For example, 1 kilometer is equal to 1,000 meters and 1 millimeter is equal to one-thousandth of a meter. Since the metric system is based on the decimal number system, i.e. based on the number 10, converting larger to smaller measures and vice versa is greatly simplified. For example, 1.234 kilograms can easily be converted to 1,234 grams by multiplying by 1,000 or simply moving the decimal point three places to the right.

The multiples and submultiples of the metric system, the same for all metric units, follow a consistent naming scheme which consists of attaching a prefix to the unit. For example, the prefix kilo stands for 1,000; 1 kilometer equals 1,000 meters and 1 kilogram equals 1,000 grams. Milli is the prefix for thousandth; 1 milliliter equals one-thousandth of a liter. Table 3 shows other prefixes, their meanings, and symbols.

Contrary to notions about its complexity, simplicity is the essence of the metric system. The simplicity of the metric system can be demonstrated by the following example. Suppose we want to add two lengths of ropes 5

feet 6¾ inches and 7 feet 8⅞ inches. To solve this problem, the fractions are converted to equivalent fractions with a common denominator and added: ¾ + ⅞ = (6+7)/8 = 13/8. Simplifying the improper fraction to 1⅝ and adding the inches 1⅝ to 6 and 8 result in 15⅝ inches. Converting 15⅝ inches to 1 foot 3⅝ inches and adding it to 5 feet and 7 feet gives 13 feet 3⅝ inches.

For comparison, the metric equivalent of the two lengths of ropes 1 m 695 mm and 2 m 395 mm can be added by simply converting them to 1.695 m and 2.395 m and adding them. The result, 4.090 m, can be converted to 4 m 90 mm by multiplying the fraction by 1,000.

Table 1—Conversion of common units from customary system to metric system

	Unit	Abbr or symbol	Equivalent in the customary system	Approximate metric equivalent
Length	inch	in or "	0 083 foot, 0 027 yd	2 540 centimeters
	foot	ft or '	12 inches, 0.333 yd	30.48 centimeters
	yard	yd	3 feet, 36 inches	0 914 meter
	mile	mi	5,280 feet, 1,760 yds	1 609 kilometers
Mass (weight)	ounce	oz	0 0625 pound	28 349 grams
	pound	lb	16 ounces	0 453 kilogram
	hundred weight	cwt	100 pounds	45 359 kilograms
	short ton	tn	2,000 pounds	0.907 metric ton
Area	square inch	sq in or in^2	0.007 sq ft, 0 000 77 sq yd	6 451 sq centimeters
	square foot	sq ft or ft^2	144 sq in, 0.111 sq yd	0 093 sq meter
	square yard	sq yd or yd^2	1,296 sq in, 9 sq ft	0 836 sq meter
	Acre	a	4,840 sq yd, 43,560 sq ft	0 405 hectare
	square mile	sq mi or mi^2	640 acres	2 590 sq kilometers
Volume	cubic inch	cu in or in^3	0 000 58 cu ft,	16 387 cu centimeters
	cubic foot	cu ft or ft^3	1728 cu in, 0.037 cu yd	0.028 cu meters
	cubic yard	cu yd or yd^3	27 cu ft, 46,656 cu in	0.765 cu meters
Liquid Measure	ounce	oz	0.0625 pint (1 804 cu in)	29 573 milliliters
	pint	pt	16 ounces (28 875 cu in)	0 473 liter
	quart	qt	2 pints (57.75 cu in)	0 946 liter
	gallon	gal	4 quarts (231 cu in)	3 785 liters
Dry Measure	pint	pt	0 5 quart (33 60 cu in)	0.550 liter
	quart	qt	2 pints (67 20 cu in)	1 101 liters
	peck	pk	8 quarts (537 605 cu in)	8 809 liters
	bushel	bu	4 pecks (1 244 cu ft)	35 238 liters
Yield	pound per acre	lb/a		1 12 kilograms per hectare
	ton per acre	tn/a	2,000 pounds per acre	2.24 metric ton per hectare
Temperature	Oegree Fahrenheit	°F		5/9 (F-32) Oegree Celsius

Table 2—Conversion of common units from the metric system to the customary system

	Unit	Abbr or symbol	Approximate customary equivalent
Length	millimeter	mm	0 04 inch
	centimeter	cm	0 39 inch
	meter	m	39 37 inches, 3 28 feet, 1 094 yards
	kilometer	km	3,280 8 feet, 1,093 6 yards, 0 621 mile
Mass (weight)	gram	g	0 035 ounce
	kilogram	kg	2 2 pounds
	quintal	q	220 46 pounds
	magagram (Metric ton)	MT or t	1 1 tons, 2 204 6 pounds
Area	square centimeter	cm^2	0 155 square inch
	square meter	m^2	10 7639 square feet
	square hectometer (hectare)	ha	2 471 acres
	square kilometer	km^2	247 105 acres 0 3861 square mile
Volume	milliliter	ml	0 006 cubic inch, 0 27 fluidrum
	liter	l	61 024 cubic inches, 0 908 quart (dry), 1 057 quarts (liquid), 0 0284 bushel
	kiloliter	kl	1 31 cubic yard, 28 4 bushels, 264 gallons (liquid)
Yield	kilogram per hectare	kg/ha	0 8922 per acre
	quintal per hectare	q/ha	89 219 pounds per acre
	metric ton per hectare	t/ha	892 189 pounds per acre, 0 446 ton per acre
Temperature	Oegree Celsius	°C	($\frac{9}{5}$C - 32) degree Fahrenheit

Table 3—Decimal prefixes and symbols

Prefix	Power of 10	Meaning	Symbol
tera	12	1,000,000,000,000	T
giga	9	1,000,000,000	G
mega	6	1,000,000	M
kilo	3	1,000	k
hecto	2	100	h
deca	1	10	da
deci	-1	0.1	d
centi	-2	0.01	c
milli	-3	0.001	μ
micro	-6	0.000 001	4
nano	-9	0.000 000 001	n
pico	-12	0.000 000 000 001	p
femto	-15	0.000 000 000 000 001	f
atto	-18	0.000 000 000 000 000 001	a

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APPENDIX

Weights, measures, and conversion factors frequently used in agriculture

Commodity	Unit	Approximate net weight	
		U.S.	Metric
		Pounds	*Kilograms*
Alfalfa seed	Bushel	60	27.2
Apples	do	48	21.8
	Northwest box	44	20.0
	Fiberboard box, cell pack	37-44	16.8-20.0
Apricots	Lug (Brentwood)	24	10.9
Western	4-basket crate	26	11.8
Artichokes:			
Clobe	½-box	20	9.1
Jerusalem	Bushel	50	22.7
Asparagus	Crate	30	13.6
Avocados	Lug	12-15	5.4-6.8
Bananas	Fiber folding box	40	18.1
Barley	Bushel	48	21.8
Beans:			
Lima, dry	do	56	25.4
Other, dry	do	60	27.2
	Sack	100	45.4
Lima, unshelled	Bushel	28-32	12.7-14.5
Snap	do	28-32	12.7-14.5
Beets:			
Without tops	do	50	22.7
Bunched	Wirebound crate	45	20.4
Berries, frozen pack:			
Without sugar	50-gal. barrel	380	172
3+1 pack	do	425	193
2+1 pack	do	450	204
Blackberries	24-qt. crate	36	16.3
Bluegrass seed	Bushel	14-30	6.4-13.6
Broccoli	Wirebound crate	20-25	9.1-11.3
Broomcorn (6 bales per ton)	Bale	333	151
Broomcorn seed	Bushel	44-50	20.0-22.7
Brussels sprouts	Drums	25	11.3
Buckwheat	Bushel	48	21.8
Butter	Box	64	29.0
Cabbage	Open mesh bag	50	22.7
	Wirebound crate	50	22.7
	Western crate	80	36.3
Cantaloups	Jumbo crate	83	37.6
Carrots:			
Without tops	Bushel	50	22.7
	Open mesh bag	50	22.7
Castor beans	Bushel	41	18.6
Castor oil	Gallon	8	3.6
Celery	Crate	60	27.2
Cherries	Lug (Campbell)	16	7.3
	Lug	20	9.1
Clover seed	Bushel	60	27.2
Corn:			
Ear, husked	Bushel	70	31.8
Shelled	do	56	25.4
Meal	do	50	22.7
Oil	Gallon	7.7	3.5
Sirup	do	11.72	5.3
Sweet	Mesh or paper bag	45-50	20.4-22.7
	Wirebound crate	40-60	18.1-27.2
Cotton	Bale, gross	500	227
	Bale, net	480	218
Cottonseed	Bushel	32	14.5
Cottonseed oil	Gallon	7.7	3.5
Cowpeas	Bushel	60	27.2
Cranberries	Barrel	100	45.4
	¼-bbl. box	25	11.3
Cream, 40-percent butterfat	Gallon	8.38	3.80
Cucumbers	Bushel	48	21.8
Dewberries	24-qt. crate	36	16.3
Eggplant	Bushel	33	15.0
Eggs, average size	Case, 30 dozen	47.0	21.3
Escarole	Bushel	25	11.3
Figs, fresh	Box, single layer	6	2.7
Flaxseed	Bushel	56	25.4
Flour, various	Bag	100	45.4
Grapefruit:			
Florida and Texas	½-box mesh Bag	40	18.1
Florida	1 3/5 bu. box	85	38.6
Texas	1 2/5 bu. box	80	36.3
California Desert Valleys and Arizona	Box	64	29.0
	Carton	32	14.5
California other than Desert Valleys	Box	67	30.4
	Carton	33½	15.2
Grapes:			
Eastern	4-qt. climax basket	6	2.7
	12-qt. basket	18-20	8.2-9.1
	Lug	28	12.7
Western	4-basket crate	20	9.1
Hempseed	Bushel	44	20.0

Weights and measures—continued

Commodity	Unit	Approximate net weight	
		U.S.	Metric
		Pounds	*Kilograms*
	W.G.A. crate	50-60	22.7-27.2
Cauliflower	Fiberboard box, wrapper leaves removed, film-wrapped, 2 layers	23-35	10.4-15.9
Horseradish roots	Bushel	35	15.9
	Barrel	100	45.4
Hungarian millet seed	Bushel	48 and 50	21.8-22.7
Kale	do	18	8.2
Kapok seed	do	35-40	15.9-18.1
Lard	Tierce	375	170
Lemons:			
California and Arizona	Box	76	34.5
	Carton	38	17.2
Lentils	Bushel	60	27.2
Lettuce	Fiberboard box, carton	38-55	17.2-24.9
Lettuce hot house	24-qt. basket	10	4.5
Limes (Florida)	Box	80	36.3
Linseed oil	Gallon	7.7	3.5
Malt	Bushel	34	15.4
Maple sirup	Gallon	11.03	5.00
Meadow fescus seed	Bushel	24	10.9
Milk	Gallon	8.6	3.90
Millet	Bushel	48-50	21.8-22.7
Molasses, edible	Gallon	11.72	5.3
Molasses, inedible	do	11.74	5.3
Mustard seed	Bushel	58-60	26.3-27.2
Oats	do	32	14.5
Olives	Lug	25-30	11.3-13.6
Olive oil	Gallon	7.6	3.5
Onions, dry	Sack	50	22.7
Onions, green bunched	Crate	60-65	27.2-29.5
Onion sets	Bushel	28-32	12.7-14.5
Oranges:			
Florida and Texas	½-box mesh bag	45	20.4
	Box	90	40.8
California and Arizona	Box	75	34.0
	Carton	37½	17.0
Orchardgrass seed	Bushel	14	6.4
Palm oil	Gallon	7.7	3.5
Parsnips	Bushel	50	22.7
Peaches	do	48	21.8
	Lug box	20	9.1
	California fruit box	18	8.2

Commodity	Unit	Approximate net weight	
		U.S.	Metric
		Pounds	*Kilograms*
Hickory nuts	Bushel	50	22.7
Honey	Gallon	11.84	5.4
Honeydew melons	Jumbo crate	44	20.0
Hops	Bales, gross	200	90.7
Pears:			
California	Bushel	48	21.8
Other	do	50	22.7
Western	Box	46	20.9
Peas:			
Green, unshelled	Bushel	28-30	12.7-13.6
Dry	do	60	27.2
	do	25-30	11.3-13.6
Pepper, green	Fiberboard carton	30-34	13.6-15.4
Perilla seed	Bushel	37-40	16.8-18.1
Pineapples	Crate	70	31.8
Plums and prunes:			
California	4-basket crate	28-34	12.7-15.4
Other	½-bu. basket	28	12.7
Popcorn:			
On ear	Bushel	70	31.8
Shelled	do	56	25.4
Poppy seed	do	46	20.9
Potatoes	Bushel	60	27.2
	Barrel	165	74.8
	Bag	50	22.7
	do	100	45.4
Quinces	Bushel	48	21.8
Rapeseed	do	50 and 60	22.7-27.2
Raspberries	24-qt. crate	36	16.3
Redtop seed	Bushel	50 and 60	22.7-27.2
Refiners' sirup	Gallon	11.45	5.2
Rice:			
Rough	Bushel	45	20.4
	Bag	100	45.4
	Barrel	162	73.5
Milled	Pocket or bag	100	45.4
Rosin	Drum, net	520	236
Rutabagas	Bushel	56	25.4
Rye	do	56	25.4
Seseme seed	do	46	20.9
Shallots	Crate (4-7 doz. bunches)	20-35	9.1-15.9
Sorgo:			
Seed	Bushel	50	22.7
Sirup	Gallon	11.55	5.2
Sorghum grain	Bushel	56	25.4
Soybeans	do	60	27.2
Soybean oil	Gallon	7.7	3.5
Spelt	Bushel	40	18.1
Spinach	do	18-20	8.2-9.1

Weights and measures—continued

Commodity	Unit	Approximate net weight U.S.	Approximate net weight Metric
		Pounds	*Kilograms*
Peanut oil	Gallon	7.7	3.5
Peanuts, unshelled:			
Virginia type	Bushel	17	7.7
Runners, southeastern	do	21	9.5
Spanish:			
Southeastern	do	25	11.3
Southwestern	do	25	11.3
Timothy seed	Bushel	45	20.4
Tobacco:			
Maryland	Hogshead	775	352
Flue-cured	do	950	431
Burley	do	975	442
Dark air-cured	do	1,150	522
Virginia fire-cured	do	1,350	612
Kentucky and Tennessee fire-cured	do	1,500	680
Cigar-leaf	Case	250-365	113-166
	Bale	150-175	68.0-79.4
Tomatoes	Crate	60	27.2
	Lug box	32	14.5
	2-layer flat	21	9.5
Tomatoes, hothouse	12-qt. basket	20	9.1
Strawberries	24-qt. crate	36	16.3
	12-pt. crate	9-11	4.1-5.0
Sudangrass seed	Bushel	40	18.1
Sugarcane sirup (sulfured or unsulfured)	Gallon	11.45	5.2
Sunflower seed	Bushel	24 and 32	10.9-14.5
Sweetpotatoes	do	55	24.9
	Crate	50	22.7
Tangerines, Florida	⅘ bu. box	47½	21.5
Tung oil	Gallon	7.8	3.5
Turnips:			
Without tops	Mesh sack	50	22.7
Bunched	Crate	70-80	31.8-36.3
Turpertine	Gallon	7.23	3.3
Velvetbeans (hulled)	Bushel	60	27.2
Vetch	do	60	27.2
Walnuts	do	50	22.7
Water 60° F	Gallon	8.33	3.8
Watermelons	Melons of average or medium size	25	11.3
Wheat	Bushel	60	27.2
Various commodities	Short ton	2,000	907
	Long ton	2,240	1,016